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LAMONT-DOHERTY GEOLOGICAL OBSERVATORY  
Columbia University  
Palisades, New York

Semi-Annual Technical Summary Report  
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→ contents:

Studies in Marine Geophysics and Underwater  
Sound from drifting ice stations.

I. Operations at Fletcher's Ice Island (T-3) and work at Lamont ; → P-13

1) Navigation

During this reporting period, the island drifted from 83°10'N, 153°20'W on July 1 to 84°52'N, 130°56'W on December 31. The drift was generally north and northeast until November when the direction changed radically to the south and southeast. In December the island's direction of motion again changed to north-northeast. The satellite navigator was operative for five of the six months and a total of 2405 satellite passes were tracked. 195 celestial fixes were obtained. More than sixty of the satellite fixes were processed by the computer on the station. The net distance traveled per month was 59.5 nm with a maximum of 97.2.

nm in November and a minimum of 48.0 nm in December. The overall distance for the period was 754 nm, and the net distance was 170 nm for a coefficient of meandering of 0.23. The island rotated  $77.8^{\circ}$  clockwise, with the island azimuth increasing gradually from  $131^{\circ}$  to  $208.8^{\circ}$ .

2) Bathymetry ;

The station left the Canada Abyssal Plain and moved over the Alpha Cordillera in early July. It remained over the Alpha Cordillera during most of the remainder of the reporting period. The precision depth recorder was in continuous operation. The average water depth during the period was about 2200 m. The recordings showed topography ranging from smooth to rough or hilly. A prominent peak rising to within 1944 m of the surface was observed on August 22 at  $84^{\circ}05'N$ ,  $144^{\circ}00'W$ .

3) Gravity ;

More than 1200 gravity readings were obtained with the Lacoste and Romberg G-27 gravity meter. A U.S. Army Map Service Lacoste and Romberg G-139 overdamped meter was held on station from October 2 to October 28 for the British Trans-Arctic Expedition. Readings were simultaneously taken with this meter and the G-27. A tie to Barrow's reference was made with both meters

on October 28. The G-27 meter was returned to station on November 14.

4) Magnetics :

Total intensity measurements were made throughout the period. Only one day of recording was lost because of instrument failure. Two magnetic storms were observed during the last week of October. They were both associated with Aurora. Another major magnetic storm was observed Dec. 19 through 21.

5) Seismic Profiler :

The seismic profiler was returned to operation on August 26 and was run continuously to the end of the period. Penetration was nominally 800 m with maximum penetration of 1500 m.

6) Hydrographic Work ; → 1-4

Both the winch and hydrohole were operative by the beginning of October. Forty-one lowerings were made: twenty-one with the tripod camera and twenty with the bottom camera/nephelometer. The bottom was commonly marked by scratches, small mounds, and rock fragments. A distinct nepheloid layer near the bottom was observed repeatedly over the Alpha Cordillera during October. Bottom currents observed during October and November were generally to the south and southeast.

#### 7) Ocean Temperature

Beginning on December 8, 22 bathythermograph lowerings were made to depths of 275 meters. The thermocline has been regularly observed at 70 to 80 meters.

#### 8) Tiltmeter

In October the housing and support for the Arthur D. Little biaxial tiltmeter were recovered from the ice and the instrument was reinstalled in an insulated vault twelve feet beneath the ice island surface. The high resolution (less than 0.2 seconds of arc) recordings of tilt have been made since October 19.

#### 9) Seismic Investigations

A short period (1 sec) Geotech Model 4681A Benioff vertical component seismometer was installed during October to investigate the seismicity of the Alpha Cordillera and to monitor vibrations from ice movement. Continuous recordings have been made since October 7.

#### 10) Scattering Layers

The scattering layer was observed on the 12 KHz precision depth recorder until the end of October. The Ross 100 KHz echo sounder was repaired and converted

to precision power in October. A faint scattering layer was observed during the third week of October, but only numerous distinct scatterers were observed during the remainder of the period.

11) Ocean Currents ;

The current meter string installed in April 1967 was retrieved during the summer and returned to Lamont for repairs. Data from nineteen vertical profiles of currents at closely-spaced intervals were analyzed. Theoretical studies of a wind-driven stratified ocean were made in an effort to explain the complex current system observed. The model incorporates a traveling surface stress which crudely resembles moving pressure systems crossing the Arctic Ocean from west to east.

12) Long-range Sound Propagation ;

The normal mode solution for point sources in a multilayered liquid-solid half space was extended to include the case of a rough ice sheet at the surface. The following computations were made by digital computer for the Arctic sound channel:

- 1) Phase and group-velocity dispersion.
- 2) Variation of pressure and vertical particle velocity as a function of depth and frequency.

- 3) Excitation as a function of frequency for constant frequency and explosive sources.
- 4) Ratio of horizontal to vertical particle velocity at the ice surface.
- 5) Amplitude spectra for explosive sources.
- 6) Peak intensity (dynes/cm<sup>2</sup>) of the first normal mode for explosive sources as a function of range and RMS ice roughness below sea level.
- 7) Oscillograms (pressure in dynes/cm<sup>2</sup>) for long-range signals from explosive sources.

In many cases the computed wave forms are in remarkable agreement with those observed. An average RMS ice roughness of 3.5 meters was determined along the transmission profiles completed last May.

## II. Marine geophysical data analysis

Unless otherwise noted, all programs discussed below are written in the FORTRAN language for an IBM 1800 system with 16,384 word memory, and IBM 1627 Model 2 30" drum plotter.

### Navigation.

Prior <sup>to</sup> April 1967, when the satellite navigation set was installed on T-3, all navigation was performed using a highly precise theodolite to observe the altitude and azimuth of the sun, moon, stars, and planets. Positions were then

obtained by hand computation using the ephemeris data in the Nautical Almanac and the solution tables in Hydrographic Office Publication #214. Navigation was tedious, and limited in accuracy by the tables and by the skill of the navigator in working up the sights. To upgrade the navigation prior to 1967, three computer programs have been developed.

The first two programs are used in place of the ephemeris tables, to calculate the Greenwich hour angle, declination, semidiameter, and horizontal parallax of the sun and stars (Program EDOC), or the moon (Program LUNE) at the time of observation. The motions of the planets have not been programmed as they are far more complex, but they may be hand entered from the Nautical Almanac or the American Ephemeris. The third program, called CELPS, takes the observed altitudes, azimuths, pressures, and temperatures for as many as six observations, along with the equatorial geocentric coordinates computed by the previous programs, and computes the following:

- a. The correction for atmospheric refraction to be applied to the observed altitude, determined from the Pulkova Observatory formulation.

- b. The latitude and longitude of the intersection of every two lines of position, determined by an iterative solution of two nonlinear equations.

c. The latitude and longitude of the center of a circle inscribed into each triangle determined by three lines of position, along with the radius of that circle in nautical miles,

d. The perpendicular distance from each line of position to the position of the smallest triangle in nautical miles,

e. The latitude and longitude determined by a least squares solution of all lines of position,

f. The azimuth of the zero line of the theodolite horizontal circle referenced to true north, and

g. The average times of all intersections and triangles determined from the original times of the observations comprising them, and the duration of the fix in hours.

Three advantages are realized from these programs. They offer up to a tenfold increase in accuracy over the methods previously used, with a concomitant savings in time. They offer a general method of accurately determining geographic position in the field with a simple surveying instrument and accurate time, temperature, and pressure information, and they allow rapid and exceedingly accurate determination of the direction of true north if one star observation is used and the geographical position is known. This last feature is used at present to provide azimuth information



on the ice island, the station positions being determined by satellite.

In order to trace the ice island's movements between celestially determined positions, another program was developed, called WDP, for Wind Derived Positions. This program uses wind observations to determine the most probable drift under the assumption that between fixes the island will move at some constant angle to the right of the wind, and at some constant angle to the right of the wind, and at some constant fraction of the wind speed. Solving for this angle and speed factor, the program then generates a position for the time of every wind observation. Interpolated positions for the navigation from 1962 to mid-1967 are very encouraging, even to the generation of characteristic loops in the track. Periods of up to 20 days between fixes have been examined.

An additional calculation is performed by the program. Nansen's rule for ice drift is assumed, i.e., drift  $30^{\circ}$  to the right of the wind at a speed of  $1/50$  the wind speed. The program then solves for the ocean current required to satisfy the navigation. The results are interesting, but no general conclusions about surface currents can be drawn as yet.

Several plotting programs have been written to enable the large quantities of navigation and observational data to be

quickly plotted on either a Polar Stereographic or Polar Azimuthal Equidistant projection. Plots can be made as overlays to existing charts, or to any desired scale. Position information may be presented as a track with line connected points, as isolated symbols, as points with time information printed nearby, or as any combination of the three. Observational data may be presented as numbers for contouring, or as symbols. For track plots, the computer can be used to calculate overall mileage. One program, called GDP for Geophysical Data Profile, can be used to present a profile view on a Polar Stereographic base. Geophysical data from a contorted track are projected onto straight line segments between given positions to produce a clear profile.

### Gravity

Two programs have been written to reduce the more than 10,000 gravity observations obtained from T-3 since 1962. The first, called GRVT for GRaVity Tie, determines the base value for the gravity meter during calibration ties at the pendulum site in Barrow, and determines the instrumental drift between ties. Earth tide corrections are computed and applied.

These results are used in the second program, called GRVC for GRaVity Calculation. This program uses the

instrumental drift, navigation, depth, and original gravity data to produce a geophysical data card with time, interpolated position, corrected water depth, total gravity, Bouguer and free-air anomalies, and if magnetic information is provided, the smoothed magnetic field strength.

The resulting geophysical data cards may then be plotted in profile form, or presented as contour maps.

### Magnetics

A computer program has been developed to accept hourly magnetic readings, and to compute hourly magnetic field strengths, each value being an average for the 24-hour period centered about that hour. In this manner it is possible to filter out most of the large diurnal variation found in the Arctic. All data from 1962 to early 1968 have now been processed in this fashion, and are available on cards.

### III. Meetings Attended and Papers Published

Kenneth Hunkins attended the Geophysical Fluid Dynamics Seminar at Woods Hole for two weeks during June and July. He returned to the Seminar on August 2nd to give a lecture on "Motions of Ice and Water in the Arctic Ocean".

#### Publications:

Hunkins, K. "Geomorphic provinces of the Arctic Ocean" in Arctic Drifting Stations, AINA, Wash., D.C.

Kutschale, H. "Seismic studies on ice island Arlis II" in Arctic Drifting Stations, AINA, Wash., D.C.

Kutschale, H. "Long-range sound propagation in the Arctic Ocean" in Arctic Drifting Stations, AINA, Wash., D.C.